

# A Strategy for Deployment of Diesel Particulate Filters (DPFs)

## An Overview of the NIOSH-MSHA DPF Selection Guide

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### Situation

- ✱ Coal rule requires use of *aftertreatment devices* to curtail DPM emissions on all nonpermissible heavy-duty diesel-powered equipment, generators, air compressors ... that emit DPM at a rate greater than 5 g/hr.
- ✱ Your management picked you to ensure that the requirement is met! – What now?

## Choices do *not* include

- ✱ Different fuels (biodiesel, water emulsions, low sulfur)
- ✱ Fuel additives
- ✱ Other devices/schemes such as “magic” gizmos and derating, i.e., anything before the tailpipe (excluding maintenance)

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## Choices include

- ✱ Disposable “paper” filter after water scrubber or dry heat exchanger, i.e., a permissible system,
- ✱ High temperature disposable filter,
- ✱ Regenerating permanent Diesel Particulate Filter (DPF)

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## Selecting options -- considerations

- ✱ Size – available space on vehicle
- ✱ Operating complexity & fit to production
- ✱ Initial capital cost
- ✱ Consumable costs (e.g., paper filters, filter cleaning, fuel additive)
- ✱ Installation complexity and cost
- ✱ Maintenance complexity & cost
- ✱ More ...?

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## Impact of aftertreatment systems

- ✱ Device installed on engine-vehicle
- ✱ May affect vehicle operation and schedule
- ✱ Imposes responsibilities on the vehicle operator
- ✱ Will require routine maintenance – engine & DPF
- ✱ May require increased technical skills

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## You're it! What now?xxx

- ✱ Attend a workshop – good, I see you are here
- ✱ Consider your options
  - ✱ What can you use
- ✱ What can't you useUse the new NIOSH-MSHA filter selection guide available *now* on the web ...

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## Deployment Details

- ✱ Filter Selection: based upon available space, exhaust temp, vehicle deployment & schedule & available systems – MUST BE A FIT between Filter and equipment
- ✱ Installation: location, mounting, vibration isolation, insulation (in some cases), isolated from combustibles, not block engine maintenance, etc.

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## Deployment Details

- ✱ Maintenance: New procedures and tasks both to engine and to the DPF. Additional pressure monitoring systems, electric regeneration systems will require service. – additional daily or PM tasks
- ✱ Equipment operator: DPF may need daily attention; back pressure monitoring and actions to be taken when it alarms...

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## Deployment Details

- ✱ Site alterations for regeneration—electrical, space, ventilation
  - ✱ Training: Maintenance & engine mechanics (could be a contractor), vehicle operator.
  - ✱ Follow-up environmental measurements: Ventilation, DPM, gas measurements if affected by DPF (NO<sub>2</sub> for example)
- Multidisciplinary task requiring coordination of several mine departments or persons who must work as a team.*

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## A Filter “Champion” is needed

- ✱ DPF deployment is not the “norm.”
- ✱ Requires additional knowledge
- ✱ Demands teamwork and cooperation of many mine people and functions
- ✱ Mine management must provide the authority and responsibility
- ✱ Must be part of the job, not incidental, not treated superficially, at least initially

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## Resources/Help

- ✱ Workshop
- ✱ NIOSH-MSHA Diesel Particulate Filter (DPF) selection guide  
[www.cdc.gov/niosh/mining/toolbox.htm](http://www.cdc.gov/niosh/mining/toolbox.htm)
- ✱ NIOSH IC9462
- ✱ MSHA & NIOSH
- ✱ [www.dieselnet.com](http://www.dieselnet.com)
- ✱ [www.deep.org](http://www.deep.org)
- ✱ Aftertreatment manufacturers

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## DPF Selection Guide - Overview

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## DPF Requirements -- Engine

DPFs collect soot → the more soot that the engine produces the more must be trapped and must be gotten rid of

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## Ensure Lowest Engine PM Emissions

- ✱ If 2-stroke engine, consider replacing it
- ✱ Properly derate for elevation
- ✱ Check oil consumption & fix if above normal
- ✱ Check CO emissions from bare engine (w/o DOC) and reduce to "normal" for that engine model; use emissions based maintenance
- ✱ Continually track & correct above items if using DPFs (best that it be done for all diesel equipment) – institute emission-based maintenance

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## ...Lower Engine PM Emissions

- ✱ Less soot to deal with
  - ✱ Longer run time on disposable filter
  - ✱ Smaller DPF possible
- ✱ How?
  - ✱ De-rate the engine, if possible.
    - Less fuel consumption
    - Less wear & tear on the tires, etc.
    - Consequence: may have to change torque converter and/or gearing
  - ✱ Consider biodiesel (untested hypothesis)

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# Exhaust Temperature Profiling

- ✱ Why profile?
- ✱ Who should do it?
- ✱ How to do it yourself

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## Why profile exhaust temperatures?

- ✱ Filter selection
  - ✱ Temp limits on high-temp “paper” filter
  - ✱ Selection of regeneration method for DPFs
- ✱ Provide details of engine loading over the shift; engine idle vs. work times, etc. – duty cycle profile

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## Who should do it - alternatives

- ✱ Yourself or your staff
- ✱ Hire a contractor
- ✱ Use a DPF supplier

Weigh the pros and cons of each, but whatever your choice, *make certain that you own the data.*

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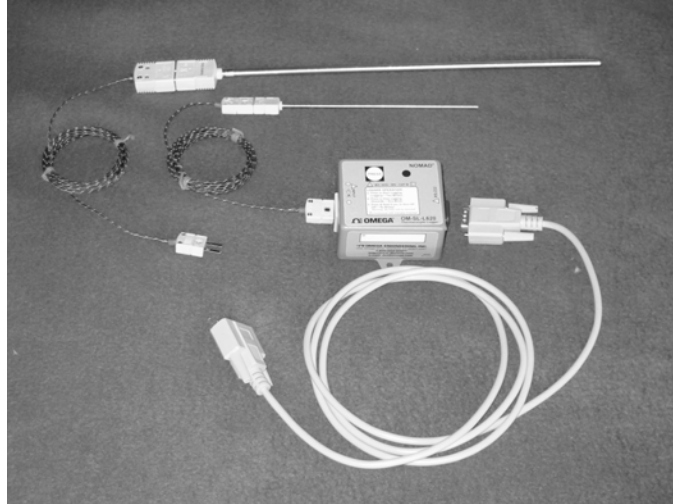
## How to do temp profiling yourself, -1

*Mention of any company name or product does not constitute endorsement by the National Institute for Occupational Safety and Health.*

- ✱ Purchase the following:
  - ✱ Type K, stainless jacketed thermocouple (TC)
  - ✱ Miniature battery-powered data logger
    - OMEGA OM-SL L620
    - HOBO H12-002 + BC3\_7-ON
  - ✱ 10' TC extension with Plug and Jack connectors
  - ✱ Pipe thread to compression fitting to hold TC

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# Temp Profiling Equipment



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## Temp Profiling, How to, – 2

- ✱ Locate TC in exhaust system where inlet to DPF would be
- ✱ Locate a place on the circumference where there is clear access for TC
- ✱ Perforate exhaust pipe with 1/2" hole and weld 1/2" pipe coupling to surface over the hole
- ✱ Install TC in fitting and adjust so tip is in the center of the exhaust pipe

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## Temp Profiling, How to – 3

- ✱ Mount the data logger in a protected location away from heat
- ✱ Route extension between logger and TC in exhaust keeping it clear of moving parts
- ✱ Use tie wraps or bailing wire to secure logger and extension wire

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## Temp Profiling, How to – 4

- ✱ Start logger at start of shift; stop logger at end of shift; identify vehicle and shift in a record book
- ✱ At end of each shift, download data according to logger instructions; reset logger
- ✱ Repeat so that the full variety of shifts for this equipment is represented several times
- ✱ Use logger software to save temperature data in degrees C as a \*.txt file compatible with Excel® or other spreadsheet software.

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# Temperature data analysis

- ✱ Load/import data into a blank spreadsheet
- ✱ Open the NIOSH analysis spreadsheet
- ✱ Copy data
- ✱ Look at results:
  - ✱ What is the temperature where 30% of the data points are higher?
  - ✱ Look at many of the shift logs and note the lowest "30%" temperature,  $T_{30\%}$  of the bunch.
- ✱ Select a DPF system

Caveat: The above is not a sophisticated analysis; DPF suppliers may use a more comprehensive analysis

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# Exhaust temperature implications

- ✱  $T_{30\%}$  is  $>325^{\circ}\text{C}$  ( $620^{\circ}\text{F}$ ) – a self-regenerating "passive" DPF is possible
- ✱  $T_{30\%}$  is  $<325^{\circ}\text{C}$  – a manually regenerated "active" DPF is required

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## Passive (self-regenerating) DPFs

- $T_{30\%} > 550-600^{\circ} \text{C}$ , uncatalyzed "bare" trap
- $T_{30\%} > 380-420^{\circ} \text{C}$ , base-metal catalyzed trap
- $T_{30\%} > 3xx^{\circ} \text{C}$ , "5g" Pt-catalyzed trap
- $T_{30\%} > 330^{\circ} \text{C}$ , lightly Pt-catalyzed trap + fuel borne catalyst (new information)
- $T_{30\%} > 325^{\circ} \text{C}$ , "50g" Pt-catalyzed trap

The above temperatures are approximate; only the DPF supplier can properly make the recommendation.

*~~UPDATED INFORMATION~~*

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## Passive DPF Considerations

- Consistent work cycle required; exhaust temperatures must always be high enough several times during shift to ensure proper soot removal
- Consequence of insufficient regeneration is the increase in exhaust backpressure
  - Increases forces on DPF (164 lbs @ 12" dia, 42 in WG)
  - May invalidate engine warranty

**MUST INSTALL BACK PRESSURE MONITOR and ALARM**

- PT-catalysts (50g loading)

Observed increase in  $\text{NO}_2$  emissions depending on Pt loading

**SAMPLE WORKPLACE FOR  $\text{NO}_2$  AFTER INSTALLING A Pt-Catalyzed DPF**

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## Passive DPF Installation Considerations

- ✱ Minimize the exhaust run between engine and DPF
- ✱ Ensure upstream pipe connections do not leak
- ✱ Insulate exhaust pipe between engine and DPF
- ✱ Insulate DPF
- ✱ Reminder: Install Back Pressure Monitor & Alarm with logging
- ✱ Continue: Temperature logging

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## Post DPF Installation Tasks

- ✱ At engine PM, make Bacharach smoke number measurement downstream of DPF – keep records
- ✱ Examine back pressure logs or interview operator about normalcy of BP readings or alarms
- ✱ Periodically (~1000 hrs) rid the DPF of ash build up (DPF Cleaning) in method approved by manufacturer

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## Bacharach True Spot Smoke Test



[Back](#)

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## Manually Regenerated (Active) DPFs

- ✱ Can be used at *any* exhaust temperature
- ✱ *Must* be used if exhaust temperature profile indicates that the temperature is under 325 to 350 °C for more than 70% of the time (equivalent to saying only 30% of the temp data lies over 325-350°C).

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## Manually (Actively) Regenerated DPFs

| <i>Regeneration Location</i> | <i>Options</i>        |
|------------------------------|-----------------------|
| Off-board                    | DPF Exchange          |
| On-board                     | On-board controllers  |
|                              | Off-board controllers |

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## Off-board Regen Considerations ~DPF Exchange~

- \* DPF size – keep small enough for one person to handle easily; use multiple DPFs for large engines
- \* Locate DPF on equipment for easy access
- \* Gas-tight flange, quick disconnect
- \* Develop DPF exchange logistics
  - \* When (between shifts)
  - \* Who
  - \* Where
  - \* DPF transport
- \* Regeneration station location

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## Off-Board Regen – Vehicle



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## Off-board regen station



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## On-board electric regeneration with On-board regeneration controller

- ✱ DPF can be located anywhere on vehicle
- ✱ Keep combustibles clear of DPF
- ✱ Need 1 – 2 hr of equipment off-duty time daily or between shifts
- ✱ Requires only a connection to electrical power for regeneration → flexible regen locations
- ✱ Moderate ventilation required during regen
- ✱ On-board controller subjected to vehicle shock and vibration → must be robust

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## On-board electric regeneration with Off-board regeneration controller

- ✱ DPF can be located anywhere on vehicle
- ✱ Keep combustibles clear of DPF
- ✱ Need 1 – 2 hr of equipment off-duty time daily or between shifts
- ✱ Requires air, sensor, power connections to a regeneration control station
- ✱ Vehicle must be parked at a control station for that system model → restricts end-of-shift parking locations
- ✱ Moderate ventilation required during regen

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## Emerging Systems

- ✱ On board manual regeneration using air intake restricted engine
- ✱ Fuel burner “passively active” regeneration

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## Post DPF Installation Tasks Manually regenerated DPFs

- ✱ At engine PM, make Bacharach smoke number measurement downstream of DPF – keep records
- ✱ Interview operator about normalcy of BP readings or alarms; do not operate vehicle for extended periods with high back pressures
- ✱ Stress to operator the need to exchange or regenerate DPF at the prescribed intervals
- ✱ Periodically (~1000 hrs) rid the DPF of ash build up (DPF Cleaning) in method approved by manufacturer

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# Filter Selection Guide

- ✱ Demo – go there

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## Resources

- ✱ Diesel-underground-L listserver  
JOIN diesels-underground-L *your name*  
*Listserv@listserv.cdc.gov*
- ✱ DPF Selection Guide – hot exhaust filters
  - ✱ MSHA web site
  - ✱ NIOSH, mining toolbox
- ✱ [www.dieselnet.com](http://www.dieselnet.com)
- ✱ NIOSH IC9462

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